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A Walk in Time and Space: My Journey as a Strategic Scientist

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Abstract

This article depicts my life and career over the past decades, beginning with my birth in 1927 and ending in my two dreams yet to be realized. This article focuses on my school years during wartime and my work with Shanghai Astronomical Observatory (SHAO) of the Chinese Academy of Sciences (CAS) from 1951 on—serving as Director of SHAO during 1981–1993 and a Member of CAS since 1980—and shares some social activities I've been involved in for the benefits of women and children. Special focus is given to the endeavors of building one of the world's most precise Universal Time systems in the 1960s, a very long baseline interferometry network, a satellite laser ranging research station during the 1970s–1990s, and the 65-m Radio Telescope in the early twenty-first century; developing astro-geodynamics in China and advancing the Asia-Pacific Space Geodynamics Program in the late twentieth century; and leading SHAO in international cooperation while serving as Chair of the International Astronomical Union Finance Committee during 1985–1988, the IAU Vice-President during 1988–1994, and a foreign fellow of the Royal Astronomical Society of Britain in 1985. This autobiographical account should, hopefully, serve its purpose of offering a glimpse of me and my lifelong interaction with time and space.

Contents

1. STARTING IN 1927

I was born into a Christian pastor's family in the city of Guangzhou, Guangdong Province, of southern China on June 21, 1927. Having already two children—and later three more after me—my father named me Shuhua Ye ("shu" means third in Chinese). At that time, Guangzhou was a composite of multifaceted elements, where the East converged with the West and modernity coexisted with tradition, a regional characteristic that has registered on my character. My father, Runsheng Ye, served as a pastor in the local Kwong Hau Christian Church, and my mother, Ruixian Cai, was a silk factory worker. She was a gentle, virtuous, and semiliterate woman with good housekeeping skills. Together, she and my father led a plain life with six children.

I have loved reading since I was a little girl. While my parents were busy with work, having no time to take care of me or teach me, I read picture books on my own and gradually I was able to read some simple books. My favorite thing to do was to explore my father's bookcase. As a child, I was able to recite/retell what I had read clearly and vividly, a talent that earned me a deep love from my family. At that time, I was fond of *The Romance of the Three Kingdoms*, one of the classics that depicted famous heroes in the Three Kingdoms period of ancient China. I was deeply attracted to the heroic spirit in the book, which left an indelible imprint on my mind. Without my sense of heroism, I could not have later led Shanghai Astronomical Observatory (SHAO) of the Chinese Academy of Sciences (CAS) out of predicaments, advanced international cooperation with my own strength, and fought tirelessly to advocate the building of a very long baseline interferometry (VLBI) network in China.

When I read, I formed my own thoughts and opinions. Through reading *The Eastern Miscellany*—an encyclopedic periodical that was quite influential in China during the first half of the twentieth century, I learned about Japan's occupation of China's three eastern provinces, and the misery in my country planted in me a seed of patriotism. Influenced by my pastor father, I read the Bible very early. When I was reading the Old Testament, I argued with my father that it was not a book to promote doctrine but a national history of Israel. My father, who was enlightened and tolerant enough to allow for free and open discussions of ideas, did not hold my dissent against me, but rather liked me more for being bright and perceptive.

In September 1939, I entered Tack Ching Girls' Secondary School in Hong Kong at the age of thirteen. After finishing the first year there, I skipped one grade, going straight to the third year, and did not feel burdened with the advanced courses. In 1941, I graduated from the school at the top of my class and went on to Hong Kong's Pooi To Middle School, a school that not only had high requirements for English but also attached great importance to music education. I joined the choir at once and learned quite a few songs. The grand scene of the choir's rehearsal of the *Messiah* is still fresh in my memory. After only four months, however, I was forced to drop out of the school due to the Japanese occupation of Hong Kong. Hong Kong fell on December 25, 1941. In April of the following year, I fled with a friend of my father to Lechang County of Guangdong Province, where I enrolled in the National No. 3 Overseas Chinese Middle School and started over from the first year of high school. Life in the school was simple and tough. In the daytime, we used a rough bamboo hut as a classroom, and at night a dozen of us shared a shanty with bunk beds in rows. Three years passed in that way when student unrest brought classes to a standstill. Soon the entire school was forced to relocate, as the Japanese invaders were pressing closer to the vicinity. I followed my parents to move again to Lian County of Guangdong Province. There, my father insisted that I continue my studies in a missionary school. So, in August 1944, I entered Pui Ying–True Light Girls' Middle School, where I met two excellent math and physics teachers, who sparked my interest in natural sciences; I also fell in love with classical music, like Beethoven's symphonies. Music has become my lifelong hobby since then, as well as a useful bridge between me and my international friends in my later engagements with scientists from other countries.

2. BETWEEN IDEAL AND REALITY

The year 1945 saw the Anti-Japanese War ended, and I came through this troubling period, graduating from high school and applying to Sun Yat-sen University, one of the best in China at that time. Originally named Guangdong University, it was founded in 1924 by Mr. Sun Yat-sen, the pioneer of the Chinese democratic revolution. When he died in 1925, the university was renamed Sun Yat-sen University in memory of him. When it came to filling in the application, my once open-minded and kind father suddenly became stubborn and had a serious disagreement with me. It turned out that I had always had a crazy audacious literary dream deep in my heart. I wanted to major in literature and, specifically, read ancient Chinese. I thought Chinese classics were so beautiful; why was no one reading them? My aspiration was to study a field that others did not and to do things that others cannot do, and nothing else would satisfy me. However, my father, who also liked literature, did not support my choice. He told me that I might even starve in the future if I studied literature, that I should study medicine or choose a major in the natural sciences for better career prospects. Having a fear of blood, I would choose to major in anything but medicine. Father talked patiently with me several times and, in the end, a compromise was reached—I promised him to apply to the Department of Mathematics and Astronomy of Sun Yat-sen University, so that I could be a teacher in the future.

I was admitted to the Department of Mathematics and Astronomy with the highest score in my district, and my family moved with me back to Guangzhou, where the university was located. As the Pacific War broke out in 1941, Guangzhou and Hong Kong fell under the yoke of Japan, and Sun Yat-sen University was forced to relocate. During the four to five years of displacement and destruction by the Japanese army, the university campus was reduced to a heap of rubble by the time China won the war in 1945. In September, Sun Yat-sen University resumed its admissions in Guangdong, and it was among such ruin that 12 newly recruited students of the Department of Mathematics and Astronomy started their university life. I was one of them.

When I entered Sun Yat-sen University in 1945, astronomy was not yet independent from the Department of Mathematics and Astronomy. Freshmen were not divided into distinct majors; instead, they were taught all basic mathematics courses along with one general astronomy course. Division of majors started during my sophomore year, putting me again in the position of having to make a choice. At that time, there was a marvelous female professor named Yixin Zou in the department, who was quite capable and conscientious and gave inspiring astronomy lectures. As a result, the whole class chose to major in astronomy, whereas before and after us only two or three students in one class chose to study astronomy. To a certain extent, Yixin Zou stimulated my interest in astronomy and led me to the starting point of my life in astronomy research. Astronomy was by then even less popular than classical literature in China. Looking around, few would know what astronomy was and what astronomy graduates could do.

It was also at Sun Yat-Sen University that I met my life partner, Jitai Cheng. He had endured many hardships in wartime and had studied mining and metallurgy at Wuhan University for three years before transferring to the Department of Mathematics and Astronomy in Sun Yat-sen University, starting his sophomore year over because of a love for astronomy. Many of his qualities attracted me, and our shared fondness for classical music brought us even closer. We fell in love naturally and got married shortly after both of us graduated from Sun Yat-sen University in June 1949. But as fresh graduates, we found that a diploma from college was no guarantee of finding a career or a living. Social uncertainty in 1949 Guangzhou aggravated the job environment. My father made inquiries around Hong Kong and found two teaching positions for us at the Tack Ching Girls' Secondary School I had studied previously, so we moved to Hong Kong and quickly became the main force of the school faculty. With well-paid jobs and my father staying with us, we lived a sort of blissful and comfortable newlywed life.

However, stable and self-sufficient teaching careers did not satisfy the two of us. We both yearned for a life of teaching in a university or researching in an observatory. In 1950, the newly founded People's Republic of China was about to rise from the ashes of economic shambles, eager for development in all sectors and in dire need of a high-tech workforce. Overseas students responded positively to the call of the motherland and returned to China with enthusiasm, ready to serve their country with what they had learned.

At that time, the Korean War had already begun, and the hidden worries of a third world war started to appear in the news. Nevertheless, I said to my father, "Even if there is a war, I am willing to stand by my 400 million compatriots, rather than stay in the tiny land of Hong Kong." My husband Jitai Cheng also said to me, "To do research back in China, we're likely to live a very hard life, a life in a thatched house and straw sandals. Are you prepared for that?" I replied without hesitation: "Sure, I've lived through much worse than that. All my middle school years were spent as a refugee."

It was in such a rising tide and with such great patriotic enthusiasm that Jitai Cheng and I came to Nanjing's Purple Mountain Observatory (PMO) of CAS for a job interview. However, they gave me the cold shoulder—PMO only wanted to hire a male (my husband) and rejected my application. Thanks to my youth and vigor, I wrote a letter to Dr. Yuzhe Zhang, the then PMO director, stating the five reasons why I was competent for the job and expressing my attitude that "It's wrong for you not to hire me anyway." In retrospect, though, the refusal was excusable. By the time we visited in 1950, PMO had been newly renamed and reestablished less than a few months prior. The entire observatory was still in its postwar recovery, and formal observations and research would have to wait for some time.

The failure did not discourage us. In August 1951, we bid farewell to Hong Kong and moved to Shanghai. Jitai Cheng found a position before me in the Department of Mathematics at Fudan University; it was not until November 19, 1951, that I received a desired offer from Xujiahui (originally spelled Ziikawei) Observatory, which later became part of SHAO, and thus embarked on my lifelong journey in astronomy. When I stepped into Xujiahui Observatory, I still believed that "Astronomy is romantic," but the difficulties and trials I encountered later at work were enough to make me change my mind at the age of twenty-five.

3. "MOTHER OF BEIJING TIME"

In 1951 when I joined Xujiahui Observatory, the observatory was the only time service unit in China. My primary task was to observe stars, reckon sidereal time, and mathematically convert it into Universal Time. The observation was conducted through transit instruments, whose precision depended mainly on the accurate measurement of the instant at which the star was on the meridian. Observation errors, although greatly reduced by technological progress, varied with the observers, instruments, recording equipment, and observation conditions, to name a few things, and were complicated enough to humble all the efforts intended to reduce their adverse effects. In a word, the observation was an extremely sensitive job that set extremely high requirements on the observers.

There I worked all day long with three other colleagues. On night shifts, I would open the movable roof of the observation room to keep the indoor and outdoor temperature consistent, thus reducing the impact of thermal radiation on our observations. As I was short in stature, I had to stand on a low stool to operate the transit instruments. Observations also required bare hands and attentive eyes all the time—to ensure the close tracking of star motion—so it was almost impossible to attend to mosquito bites in sticky summer or frostbite in frigid winter while operating the instruments. Data processing was another challenge because we lacked modern computing tools, not to mention computers; the only tool available was the traditional abacus, making the job miscellaneous with trifles.

The repetitive task, dreary and cumbersome, kept going on and on, and I did not quite understand the reasoning for it at the very beginning. Was I doomed to do this job all my life? After all, it was far from my perception of astronomy. It was not until later that the answer gradually came to me and I flung myself into a lifelong career. As is now known, Universal Time provides a time benchmark based on the rotation of the Earth. An accurate standard time was essential for geographic surveying and mapping, navigation, and exploration, whereas an inaccurate measurement might generate counterproductive effects. Unfortunately, the equipment we were using at SHAO failed frequently. Whenever the automatic instruments stopped working, one of my colleagues, Dingjiang Luo, a skillful operator with over twenty years of experience, would manually broadcast the time numbers in standard format and, among the four of us operators, only he could do the job. As can be guessed, China's time service was then among the world's least accurate.

In 1954, the State Council reached out to CAS with the task of improving time service and SHAO was appointed specifically to the job. CAS also decided to participate in the ambitious worldwide program the International Geophysical Year, particularly the third joint longitude survey project (the first took place in 1926 and the second in 1933). The dual undertakings impelled SHAO to be better staffed and equipped. A fair-quality batch of astronomy research and engineering faculty and students was brought in each year; a photoelectric transit instrument from the Soviet Union, a Danjon astrolabe (**Figure 1**) from France, and a large quartz clock from Germany were purchased. Accordingly, SHAO's time broadcasting caught up with the international advanced level in terms of accuracy, though it still relied on the standard time systems of the Bureau International de l'Heure (BIH) and the Soviet Union. By the time I started leading a team of SHAO scientists to work on the timing project in 1958, our job had transformed from improving the time broadcasting to building China's own integrated Universal Time system.

In principle, an astronomical observatory sets a Universal Time through astronomical observations and broadcasts it by radio signals in a certain format, which are called time signals. Astronomical observations cannot be done every night, being confined to clear nights; but time signals, to be exact, need to be broadcasted every day. For that reason, a preliminary Universal Time is set for the purpose of time broadcasting, and after that, a more accurate Universal

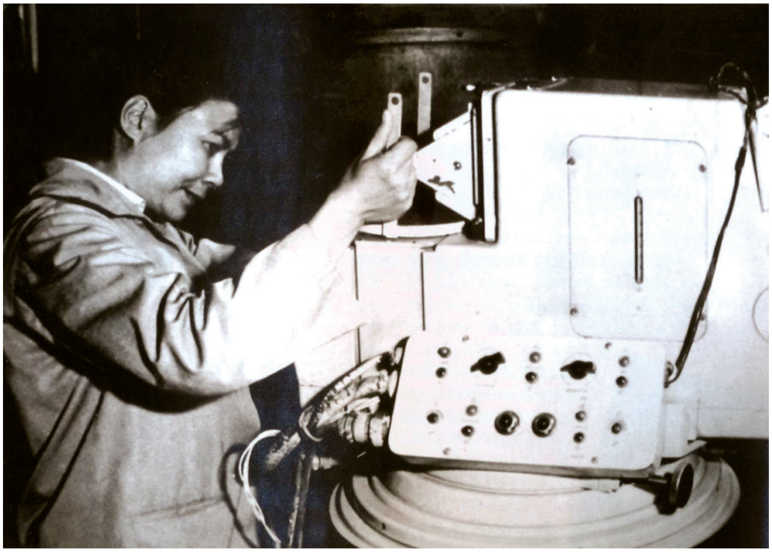

Figure 1

Shuhua Ye operating the Danjon astrolabe, Shanghai, China, 1964. Photo provided by Shanghai Astronomical Observatory.

Time is determined based on two-to-three-month observations to correct time signals already broadcasted. The corrections are used for the final reduction in geographic surveying and mapping.

In astronomical observations, there are errors derived from the observers and the instruments, which can be reduced via photoelectric methods but cannot be eliminated. In order to build and maintain a stable correction system, we followed at the outset the BIH principle, assuming that the sum of systematic deviation of the stations involved was zero. But later we found that, regarding the number of timing stations, our system (with only 2 stations) was far too different from that of BIH (with 39 stations) and the Soviet Union (with 14 stations) to copy their methods. I did tests for months and found at length a new approach. My assumption was that the sum of changes of the systematic deviation was zero. Specifically, a mathematical model was applied to keep the Universal Time system stable and the weighted mean of changes of the observer' personal and instrumental errors zero. In this way, effects of sudden changes of individual instruments could be overcome, making it especially suitable for systems with fewer stations, though a new incoming instrument would be subject to an over one-year probation period to identify changes of its personal and instrumental errors and thereby determine its weight. The new model greatly improved the accuracy, and we've been applying it ever since.

Between 1960 and 1963, more instruments from Beijing Astronomical Observatory and the Institute of Geodesy and Geophysics of CAS joined our timing system. Meanwhile, I paid special attention to improving observational methods and catalogs as well as applying advanced instruments, including level gauges, photon counters, microcomputers, etc. In 1963, with only six instruments from 5 stations, China's Universal Time system leaped into the world's top three in precision (±2.0 milliseconds), which was almost on a par with the BIH system (with 39 stations in 21 countries) and surpassed the Soviet Union standard time system (with 17 stations in four countries). In 1965, the system passed state verification and was set as the national time benchmark in China. That is how "Beijing Time" came into being.

The synergy between SHAO and the other four observatories concerned enabled China's system to maintain a global leading position for a long time. According to a calculation of observation accuracy during 1978–1982 conducted by the Japanese International Polar Motion Service (IPMS) on 40 global instruments, the photoelectric transit instrument of SHAO ranked the world's second in precision. Between 1978 and 1982, P. Paquet [President of the International Astronomical Union (IAU)'s Commission 19: Rotation of the Earth], K. Yokoyama (the IPMS President), and G. Wilkins [Chairperson of the IAU/IUGG (International Union of Geodesy and Geophysics) Working Group on the Rotation of the Earth] all mentioned that China's time and latitude observations helped improve the accuracy of the Earth rotation parameters (ERP; including the Universal Time and the polar motion).

4. VERY LONG BASELINE INTERFEROMETRY IN CHINA

While astronomy flourished worldwide in the 1960s and 1970s, the Chinese academic community was hit by the Cultural Revolution. Like many other intellectuals, I was forced to leave my beloved job and live in the so-called cowshed. The major job assigned to me was to clean up the SHAO library in Sheshan. There, against all the odds, I got the chance to read foreign publications and follow up on where global astrometry was heading. In the early 1970s, I noticed a new global trend and thought China should take actions immediately, otherwise its advantage gained in ERP measurement would be lost. The new trend was the emergence of the new technologies satellite laser ranging (SLR) and VLBI in the late 1960s.

I proposed at first to do experiments using laser gyroscopes to measure the Earth's rotation. However, it set such extremely high requirements on technology and the surrounding environment that we had to give up after five years of experiments, and so did our counterparts overseas. By the 1990s, both New Zealand and Germany had successfully developed laser gyroscopes to measure the Earth's rotation and polar motion, but it was not until the beginning of the twenty-first century that their efforts yielded initial scientific returns.

Unlike SLR, which measures the round-trip distance between an instrument on the ground and a reflective satellite in orbit, VLBI measures the positions of ground radio antennas with respect to distant radio sources, which is essential for the Celestial Reference Frame (CRF) when observing the Earth orientation parameters (EOP). The technique is, in short, to unite several small radio telescopes to achieve the observation effect of one large telescope in terms of angular resolution. The VLBI network plays an indispensable role in fast and high-precision orbit determination and positioning of lunar and deep space probes.

However, back in the early 1970s when I first suggested developing China's VLBI system, the technology was not even regarded as promising. Few were optimistic about its prospects. At that time, even in America and Canada, which were the earliest ones involved in this field, the VLBI-related theories and technologies were still in their infancy and met with skepticism. In China, if a VLBI network was to be established, at least three radio telescopes with diameters of at least 25–30 m had to be built in sites far away from each other. Besides technical challenges, the unprecedented project also meant a large demand for funding, making it all the more difficult in 1970s China.

But I believed VLBI promised an extensive use in astrometry and astrophysics, with the highest precision and resolution in astronomical observations. It was a big chance we should bet on if China wanted to stand at the forefront of the world in astrometry. If we missed it, we would miss the future. With this belief, I seized chances afforded me to highlight among the Chinese astronomical community the significance of developing the new technology and sought the means possible to promote the VLBI project.

Figure 2

Shuhua Ye in front of the Sheshan 25-m Radio Telescope, Shanghai, China, 1987. Photo provided by Shanghai Astronomical Observatory.

At length, the VLBI initiative caught the attention of CAS and was shortlisted for its major scientific research projects from 1974 to 1975. We set up a dedicated working group in SHAO for the equipment development, observation organization, data processing, and scientific research and, gradually, we established the SLR and VLBI systems. In order to accumulate experiences on the development of a VLBI system, I led the project team to start the construction of an experimental VLBI system with 6-m radio telescopes in 1975. One of the 6-m radio telescopes successfully carried out a VLBI experiment with the Effelsberg 100-m Radio Telescope of the Max Planck Institute for Radio Astronomy, Germany, in November 1981. The VLBI project of SHAO was approved by CAS and officially launched in the early 1980s, consisting of three radio telescopes and a data processing center. The first one was the Sheshan 25-m Radio Telescope in Shanghai, which started construction in 1981 and completed in 1987 (**Figure 2**), followed by another 25-m radio telescope in Urumqi, Xinjiang Uygur Autonomous Region, in northwest China in 1994. Unfortunately, construction of the third radio telescope was postponed due to a lack of funding. In the early 1990s, we completed construction of the basic VLBI network, and the SLR network across five cities in China despite the odds technically, financially, and ideologically. Funding, for example, was extremely tight at that time. There was even a rumor going about that all the scientific research funds for the Chinese astronomical community were used by me alone.

In 1979, the IAU and the IUGG jointly led a worldwide campaign to intercompare all the techniques available for determining the ERP and to advance new technologies, the so-called MERIT campaign, short for "A program of international collaboration to Monitor Earth-Rotation and Intercompare the Techniques of observation and analysis." A working group was set up to this end among the global scientific community, and I was one of its members. When the MERIT short campaign was held between August and October 1980, I led the MERIT operations in China encompassing classical optical observations, SLR and Doppler observations. Based on the test results and organizational experience gained in the short campaign, the MERIT main campaign was conducted between 1984 and 1985 and with participation by more than 60 observatories from over 20 countries. In August 1985, a conference summarizing the MERIT program of activities was held at Ohio University, USA. On behalf of SHAO, I presented the reduction results of such observation techniques as classical astrometry, VLBI, SLR, LLR (lunar laser ranging), and Doppler. In a time when most Chinese agencies focused more on optical observations, SHAO was the only observatory able to deal with such a wide variety of observation data. According to the conference summaries, the new ERP observation technologies were dozens of times more accurate than traditional optical astrometry.

A continuation of the test campaign till mid-1986 was agreed on to obtain more confirmed conclusions. Later in 1987, the IAU/IUGG decided to replace classical astronomy with the new techniques in all the ERP-related global collaborations, and many observatories in China and beyond terminated their optical services accordingly. As of 1988, BIH and IPMS, both participants of the IAU/IUGG optical observations, stopped operations. BIH was reconstructed into the International Earth Rotation Service (IERS) and, through adoption of the new technologies, expanded their reach to preside over the CRF and the Terrestrial Reference Frame (TRF). The former relied on VLBI observations, whereas the latter relied on VLBI, SLR, and the Global Positioning System (GPS). With all these techniques already, SHAO was the only base station in Asia for the TRF from 1994 on, whereas it was not until recently that neighboring countries such as Australia, Japan, and South Korea began to build similar base stations. Since then, the VLBI stations in Shanghai and Urumqi have participated in the CRF, TRF, and EOP VLBI observations organized by IVS (the International VLBI Service for Geodesy and Astrometry) and IERS. Later through the Asia-Pacific Space Geodynamics Program (APSG), I organized annual VLBI observations across the Asia-Pacific regions. Also, Shanghai and Urumqi VLBI stations participated in the VLBI observations of the European VLBI Network, the Crustal Dynamics Project (CDP), and Dynamics of Solid Earth (DOSE) projects of the US National Aeronautics and Space Administration (NASA) and the Chinese–Japanese joint VLBI observations, including the VLBI Space Observatory Programme of Japan.

5. THE 65-METER TIANMA RADIO TELESCOPE

Our endeavor to build the 65-m Tian Ma Radio Telescope was another journey of twists and turns. In the beginning of 1993, I and my team initially proposed the construction of a 65-m radio telescope as the national mega-science project for the sake of further development in radio astronomy and deep space exploration. Although the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) was selected as the national project instead, SHAO continued the advanced research of the 65-m radio telescope and kept track of the latest technology and global developments of large radio telescopes. Later in May 1998, SHAO proposed again the construction of a 65-m radio telescope in a joint conference held by CAS and the National Natural Science Foundation of China, but still it did not get the support.

In 2003, one year before the launching of China's Lunar Exploration Project (CLEP), I and my team at SHAO took the initiative to request the use of VLBI technology in the measurement of lunar probe orbits, which was adopted on the CLEP overall scheme demonstration meeting. In

2004, the Shanghai Sheshan 25-m VLBI station participated in the VLBI-based orbit determination of the lunar probe SMART-1 launched by the European Space Agency (ESA) in 2003, and in 2005 it was involved in the NASA/ESA Mission to Saturn, observing the whole process of ESA's Huygens probe entering into the atmosphere of Saturn's moon Titan. These great successes built experience for CLEP.

On October 24, 2007, the CLEP Chang'E-1 was successfully launched in the city of Xichang. Our super telescope, composed of four VLBI stations and with a diameter equivalent to more than 3,000 km, was officially put into use, assisting with the Chang'E-1's flight to the Moon. For a continuous 53 days, the VLBI orbital determination subsystem carried out quasi-real-time tracking and measurement each day, from the phasing orbit to the lunar orbit. This is the first time that VLBI technology has been applied to aerospace engineering in China and the first time in the world that such technology has been applied to quasi-real-time orbital determination in lunar exploration.

SHAO became the principal contributor to the VLBI technology for the CLEP project. In January 2008, Shanghai municipal government officials received the Shanghai working group on CLEP in celebration of the success of Chang'E-1, and once again, we put forward the initiative to build a new antenna, as the existing antenna of the Shanghai VLBI station had already passed its service life. This time, much to our delight, the Shanghai municipal government agreed to jointly launch a project with CAS officially in late 2008 and build a 65-m radio telescope in Shanghai, aiming to apply the telescope in the exploration of not only the Moon but also Mars, Jupiter, and the edge of the Solar System. With strong collaboration of relevant domestic institutes and productive advice from international experts, the 65-m Tian Ma Radio Telescope was successfully completed in October 2012 and began to play an important role in China's astronomical research and deep space exploration. In 2019, the project won the Special Shanghai Science and Technology Progress Award.

6. "NO MAN'S LAND"—ASTRO-GEODYNAMICS

The difference between classical astronomy and the new emerging technologies was, in principle, a change from angular to distance measurements. High-precision atomic clocks made it possible to measure time by distances instead of angles, contributing to a much higher precision. In addition, the simultaneous determination of EOP in no less than two stations would also accurately measure the distance between the stations, and changes of the distance would reflect the crustal movement and plates deformation, which can then be used in the study of crustal dynamics and environmental changes, such as earthquakes, volcanic eruptions and sea-level changes, and the interactions of multiple spheres of the Earth. That brought us to a new interdisciplinary field—astro-geodynamics.

For a long time, astro-geodynamics had been a "no man's land" in China. Astronomy had no connection with geosciences; surveying and mapping interacted with neither oceanography nor seismology. Nobody thought about bringing the miscellaneous fields together. Because we had the new technologies, it came to me: Why not seek a multiagency, cross-cutting development of astro-geodynamics?

In 1978, I led a team of astronomers from SHAO and three other Chinese observatories to visit corresponding French agencies, including 10 astronomical agencies under the French National Institute for Astronomy and Geophysics (updated now as the National Institute for Earth Sciences and Astronomy) and 7 closely related agencies. We had an in-depth discussion with BIH and the newly built French Center for Astro-geodynamics Research and were inspired by their forefront research and technology. Back in China, we expanded our work to the astro-geodynamics field and set up a comprehensive network of new techniques covering VLBI, SLR, and GPS.

At the end of 1989, I took a business trip to CAS in Beijing and heard that the State Scientific and Technological Commission of China was about to launch a batch of key fundamental research projects, the so-called Climbing Campaign. I asked the commission for more information but was told it was too late to apply, as all 10 slots had already been filled. I requested to have a further look at the guidelines and found that my ongoing project on China's crustal motion fitted perfectly, so I immediately organized a team of experts from diverse institutes, including CAS, the State Bureau of Surveying and Mapping, the China Earthquake Administration, etc., to apply and got the fifth of the 10 projects. In 1991, I became the chief scientist of the 10-year national Climbing Campaign project "Modern Crustal Movement and Geodynamics Research," thereby initiating astro-geodynamics research in China.

In studying the crustal motion in China, the influence of the surrounding tectonic plates motion should not be excluded. China is in the Asia-Pacific region, a region characterized by dense population, booming economics, and frequent natural hazards (fierce earthquakes, volcanic eruptions, tsunamis, etc.); it is one of the regions in the world that urgently needs research in plate tectonics, crustal motion, and deformation, and sea-level change. The local features offered scope for cooperation, but there had been none such multiparty research across the region. With an advantage already gained in the domestic portion of the project, I and my team thought about expanding the Climbing Campaign project to the wider Asia-Pacific region, pooling together all relevant scientists to cooperate and contribute to the prediction of major disastrous events. Besides China, the region is represented by countries like Japan, South Korea, and Australia. I talked to scientists of these countries about the joint research initiative and gained support from them.

In September 1994, the First Ministerial Conference on Space Applications for Sustainable Development in Asia and the Pacific was held in Beijing, China. I signed up for the pre-symposium consultations, in which I proposed the establishment of APSG and got it listed among China's proposals to be discussed during the symposium. However, I became anxious listening to discussions of one proposal after another without hearing any mention of mine, and the symposium was nearly ready to end. Without hesitation, I raised my hand on the spot to present my initiative—I described how it fit into the spirit of the symposium and why it should be listed in the last resolution that was under discussion. Having heard my proposal, the Chairperson of the symposium promised me to list it exclusively as one extra resolution. So, then came Resolution No. 25. I was quite glad that hurdle had been crossed, yet I was told afterward that a resolution can hardly be realized without support from the international academic community.

The following year, the Twenty-first IUGG General Assembly was to be held in Colorado, USA, from July 2 to 14. I thought this was the exact chance to solicit the necessary support, so I applied for a specific APSG seminar to be arranged on one night of the assembly. Previously during my visits to NASA and relevant European institutes, I had introduced the APSG initiative and gained their support; domestically, my presentation of the APSG plan had been unanimously supported by institutes including CAS, the State Bureau of Surveying and Mapping, and the China Earthquake Administration. Everything went well, except that days before I set out for the Colorado conference, my husband got a femoral neck fracture after a bicycle fall and had to undergo a major surgical operation. I could not wait for another chance. The quadrennial conference was three days after his surgery, but still I set off as planned, apologizing to my husband, who understood my situation and fully supported me.

Sparks flew at the seminar, as the APSG initiative was challenged by many foreign counterparts who doubted whether China would be able to preside over the work, but I was poised to address all the worries. In the wake of a heated debate, a NASA scientist stood up in support of me, and finally the proposal was passed. Representatives from four other countries even offered to assist in preparing the draft. As a result, Resolution No. 4 of the International Association of Geodesy

(IAG; a subordinate association of IUGG) stated its clear endorsement for APSG, encouraged scientists all over the world to join in, and agreed that I continue to advance the APSG initiative.

When the first APSG conference was held in Shanghai in 1996, I was elected as its first president and SHAO as the headquarters of its central bureau. Never before had the Chinese astronomical community initiated such a large-scale international cooperation project. Scholars and experts from nearly 20 countries and regions, including China, the United States, Australia, Japan, South Korea, Russia, Germany, France, Indonesia, etc., participated in the program. Its first executive committee consisted of scientists from China, Japan, the United States, Australia, Russia, and Indonesia. Since then, the ongoing APSG has promoted international academic exchange and scientific cooperation and enhanced the scientific research level of developing countries in the Asia-Pacific region.

APSG was one big happy family, for both me and my international friends as well. Each closing ceremony of the APSG Annual Assembly would culminate with performances by scientists from different countries. I would lead off with a song and following me, one after another would go on the stage for a lively performance. We enjoyed the time together with laughter and music, the universal language that binds all hearts and souls.

7. VICE-PRESIDENT OF THE INTERNATIONAL ASTRONOMICAL UNION

"We welcome astronomers from all over the world. Although we come from different cultures, we share the same goals in astronomical research." That was what I said during the XXVIII IAU General Assembly held in Beijing in 2012. Global organizations like APSG and the IAU offer opportunities for multiparty communication and collaboration, which has always been one of my special focuses. During my tenure as Deputy Director (1978–1981) and Director (1981–1993) of SHAO, I facilitated the Chinese observatories' joining in the international VLBI, SLR, and GPS services and worked continuously to promote joint campaigns and collaborative research between China and other countries, such as the China–France SYMPHONIE satellites time synchronization mission, the time comparison between China and the USA for carrying clocks, the China–Germany VLBI survey, the China–Japan VLBI survey, the transoceanic balloon flight project between China and Japan for scientific observations in space astronomy, and the International Atomic Time cooperation.

Back in 1978, development of SLR and VLBI was a challenging task for China. That year, China started its reform and opening-up policy, and I turned my gaze toward international collaborations. It happened that Professor Zongfen Guo of Columbia University visited Shanghai, and I, on behalf of the Shanghai Association for Science and Technology, received him. When Professor Guo learned that SHAO was already developing VLBI and SLR technology but lacked exchanges with international institutes at the forefront, he offered to introduce us to relevant American institutes. Soon afterward, NASA and McDonald Observatory sent us invitation letters. In April 1979, I led a team to visit the relevant subagencies of NASA, the Department of Astronomy at the University of Texas at Austin, McDonald Observatory, and Austin's Center for Space Research, thus opening a new chapter on the bilateral collaboration with regard to VLBI and SLR and, later, key equipment development and data processing.

China became a national member of the IAU early in 1935 but decided to exit in 1960 when Taiwan joined as a member. In August 1979, a Chinese delegation of six people led by Director Yuzhe Zhang attended the XVII IAU General Assembly in Montreal, Canada, with the purpose of restoring China's legal seat in the IAU. Due to the delegation's adherence to the One China policy and the constructive attitude of the IAU, led by its then President Adriaan Blaauw, the IAU finally decided to refer to its two members across the Taiwan Straits as, respectively, the China (Nanjing) and China (Taipei) astronomical societies. As one of the six delegation members, I reported at the conference the research progress of China in the IAU's Rotation of the Earth. China formally restored its membership at the following XVIII IAU General Assembly held in Greece in 1982. Impressed by our work on Universal Time, the President of the Commission 19: Rotation of the Earth especially welcomed our participation in the MERIT campaign. I was selected as an organizing committee member of Commission 19: Rotation of the Earth, Commission 31: Time, and Commission 38: Exchange of Astronomers.

At the XIX IAU General Assembly in New Delhi, India, in November 1985, I was elected as Chair of the IAU Finance Committee, which made me the first ever Chinese astronomer to take an IAU position. My election and my work at the IAU were greatly supported by the then IAU General Secretary Richest West. During my tenure, the IAU tilted toward a slightly larger portion of funding for the third world, so that the relatively poorer countries could be afforded the chance to hold regional IAU conferences.

In 1988, just ahead of the XX IAU General Assembly, I received an unexpected letter from the then IAU president Jorge Sahade, in which he mentioned that the IAU Special Nominating Committee decided to recommend me as one of the next Vice Presidents. My election at the XX General Assembly made me the second female IAU Vice President and the first from Asia. I was re-elected three years later at the XXI IAU General Assembly in Buenos Aires, Argentina (**Figure 3**). From then on, more and more Chinese voices were heard in the IAU academic meetings, and furthermore, Beijing became the hosting city for the Asia-Pacific Regional IAU Meeting in 1987 and later the XXVIII IAU General Assembly in 2012.

Besides serving on quite a few divisions and committees organized by the IAU, I also served with many other international agencies and was elected as a foreign fellow of the Royal Astronomical Society of Britain in 1985. In late 1980, I went to the United States for three months at the invitation of the American National Geodetic Survey. There I studied as a senior scientist the precise location of radio sources via VLBI and worked closely with astronomers from the United States Naval Observatory and NASA's Goddard Space Flight Center. Back in China, I facilitated collaboration between CAS and NASA. On behalf of CAS, I signed the Joint Research Proposal between CAS and NASA in May 1982 and participated from 1982 to 1991 in the NASA CDP project. In June 1996, CAS extended its collaboration with NASA by joining the follow-up DOSE project, and I served as the Chinese coordinator. With the efforts of multiple parties, SHAO has established extensive cooperative relationships with NASA and other global agencies.

Figure 3

XXI IAU General Assembly, Buenos Aires, Argentina, July–August 1991. Shuhua Ye with three other IAU Vice Presidents. Photo provided by Shanghai Astronomical Observatory.

8. WORKING FOR THE WELL-BEING OF WOMEN

As a female scientist, I have always cared for gender equality, women's education, and women's participation in political and social life. When the United Nations Fourth World Conference on Women was held in Beijing in 1995, I delivered a speech at the conference to encourage women to break the "glass ceiling" and fulfill their potentials. The conference had extensive participation from over 160 countries and was considered a landmark in the women's movement and gender parity campaign. Women from all parts of the world gathered to share their experiences of encountering inequality and discrimination in public and private life in both subtle and blatant ways. We recognized the tight squeeze faced by women universally and worked together to chart a way forward.

From 1998 to 2011, I served as Chairperson of the Subcommittee on Women Talents of the Chinese Association of Human Resource Development, which provided a proper venue for activities related to women's development. In November 2021, the World Laureates Association SHE Forum of the Fourth World Laureates Forum was held in Shanghai, and I was invited to give a keynote speech, in which I encouraged women to strive for gender equality. The speech had great influence in China and beyond, partly reflecting the ever-rising power in the women's movement.

We are living in a time when women can get into fields they were barred from in the past and become an essential element, not only in politics and engineering but also in astronomy; yet we are living in a time when women still suffer from a bias rarely faced by men, such as facing more pressure in balancing a career and family or being more likely to face unfair treatment in career development and social life. Women are just as capable as men even though there are physical and biological differences. Through personal effort, women can do much better than men, although that possibly means working twice as hard as men on the same basis coupled with seizing all the opportunities they can. To be sure, there is still a long way to go in the pursuit of gender equality, but we must have the courage to set out to make a difference.

9. OUTREACH TO YOUNGER GENERATIONS

Public outreach in astronomy, especially to our children, is another everlasting endeavor of mine. I proposed the construction of Shanghai Astronomy Museum in 2010, thinking that the museum would help shape young people's understanding of the Universe. The museum began construction in 2016 and officially opened on July 17, 2021, becoming the world's largest astronomy museum. During my tenure as President of the Shanghai Association for Science and Technology between 1996 and 2001, I organized science forums inviting Nobel laureates, renowned scientists, and government leaders worldwide to give lectures on science and technology. I also gave lectures via radio, film, and television to help promote public awareness of astronomy and science. Interaction with primary and middle school students was always quality time for me—I would marvel at their curiosity and imagination, answer their whimsical questions, and offer guidance on conducting science experiments.

The following analogy illustrates my perception of the work. If we say scientists charge and discharge 380 V in their daily work, whereas the general public can only receive 220 volts, then what popular science does is convert 380 V to 220 V so that science can get across to the general public. Building an astronomy-literate society is of great significance, and the greater significance lies in training future generations of scientists, drawing our children to the exploration of the marvelous field of the unknown and engaging them in a future career in science and technology. After all, to be young means to be curious and creative.

I even talk to the young generations about the Square Kilometer Array (SKA) project China is involved in, telling them it is a super telescope, surpassing any existing astronomical equipment in precision, that is expected to offer solutions to the most fundamental scientific questions of our time, such as the birth of planets, the traveling of gravitational waves—the so-called cosmic ripples—in spacetime, the formation and evolution of the first galaxies, etc. I hope among them there will be future participants in the project who will use their wisdom to solve the problems that are currently unsolved and make their contributions to the great cause.

10. STILL ON THE ROAD

Time seemed to be of prodigious length, yet it passed like a flash. Looking back, I have walked with SHAO through ups and downs for over 70 years (serving as its Director from 1981 to 1993), and received in the meantime a few other honors—I was elected a Member of the CAS in 1980; I've served as Honorary President of the Chinese Astronomical Society since 1988; and Asteroid 3241 is named after me (**Figure 4**), to mention a few. I'm still working in my office every day and participating at times in new, exciting projects. Friends and colleagues urge me now and then to enjoy a retired life away from work, but I cannot, and would not, as I still have two dreams to realize.

My first dream is to build the SKA Regional Center (SRC) in China. As I mentioned earlier, SKA is a worldwide cooperation of low-frequency radio observatories and a leading research infrastructure based on an unprecedentedly huge data processing ability. Once completed, it is expected to be the largest ever and most advanced radio telescope.

China's participation in SKA started early in its embryonic stage. In August 1993, when I attended the XXIV General Assembly of the International Union of Radio Science in Kyoto, Japan, one theme we talked about at the conference was how to build future large telescopes. The Dutch scientists came up with the idea of assembling a number of small components into telescope units of equal size; the Canadian scientists suggested a combination of a relatively large telescope on the ground and a balloon in air, with a reflector on it; a few European scientists held the opinion of assembling small telescopes; and the Chinese scientists proposed to build more than 30 large-diameter telescopes. It was this round of intense discussion that gave birth to the initial idea of SKA and the following joint initiative to build a giant radio telescope with a total collecting area

Figure 4

Asteroid 3241 is named after Shuhua Ye, 1997. Photo provided by Shanghai Astronomical Observatory.

Figure 5

2019 SKA Shanghai Meeting, Shanghai, China, November 2019. Shuhua Ye is third from the right in the front row. Photo provided by Shanghai Astronomical Observatory. Abbreviation: SKA, Square Kilometer Array.

of approximately one square kilometer and a sensitivity two orders of magnitude greater than the current largest telescope in the world.

Efforts were made across the world for the mega-science project, and in China, the Five-hundred-meter Aperture Spherical radio Telescope (FAST) was built in a karst depression of southwest China as a trailblazer. This so-called China Sky Eye is by far the world's largest single-dish radio telescope with the highest sensitivity. Its unique design of a 300-m spherical reflector able to be adjusted instantaneously into a paraboloid has brought the relevant technology to a new height, not only for China but also for the whole world. However, due to careful considerations, the two SKA telescopes were finally set in South Africa and Australia—both radio-quiet sites in the Southern Hemisphere with a perfect view of the Milky Way. Although China failed to be selected as the site, we have been and will be a major player in the SKA project.

China was one of the founding signatories to the Convention on the SKA Observatory (SKAO) in March 2019; later in November, SHAO was the local organizer of the 2019 SKA Shanghai Meeting (**Figure 5**); and in June 2021, China became a full member of the SKAO Council, participating in the operation and management of the observatory and the design, research, and development of the project; and now, China is thinking about making greater contributions to the SKA cause. SKA data flow is expected to match the sum of the entire Internet, and to handle the vast volume of data requires a global network of SRCs. We are underway to build one of them. At the end of 2019, the China SKA regional center prototype was developed by SHAO to provide its users with computing resources, data products, and technical support—not only the first of its type in the world but also a precursor to the future China SRC.

The other dream of mine is about space VLBI. VLBI technology has achieved a very high resolution nowadays but not fully in space. Though Japan and Russia have each established space VLBI, it is only a single telescope with a diameter of less than 10 m in contact with the ground. Our plan is to send two 30-m low-frequency radio telescopes into space. The telescopes should be able to operate alone in space or cooperate with ground facilities, such as carrying out continuous testing with SKA and FAST. If successful, it is expected to solve some currently contentious issues in astronomy and, hopefully, explore new fronts.

These dreams, though they were blue-sky thinking at the outset, stand a good chance of being realized, but only if we keep working toward that goal. Life is a journey studded with surprises, and my theory is that if we start with, say, a 40% chance of success, the chances would reduce gradually to zero if we stand there doing nothing, but they rise to 60%, 70%, and in the end 100% if we take action and strive hard for it.

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